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The Latest Measures and Tools for Energy Management, Ecology, Labour Protection, and Human Life Safety

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Abstract

The study aimed to identify innovative mechanisms in energy resource management, environmental protection, and ensuring labour and life safety used in various European countries. The methodology included examining the latest measures and tools in energy management, ecology, labour protection, and human life safety, conducted based on a comparative analysis of Ukraine with such foreign countries as Germany, Sweden, and Japan. The study was based on an analysis of the scientific literature and regulatory documents governing these areas. The main results of the study show that the introduction of automated energy management systems substantially reduces energy costs and greenhouse gas emissions, which has a positive impact on the environmental situation. In the field of labour protection, the introduction of the latest personal protective equipment and safe technologies helps to reduce the level of occupational injuries. In the field of life safety, the effectiveness of emergency early warning technologies and emergency response systems has been confirmed. The results obtained indicate a substantial potential for using modern technologies to improve the efficiency of resource management and security. Improving these technologies and adapting them to specific conditions and needs will ensure more sustainable and safe development in the future. The study concludes that the integration of modern early warning systems and efficient response mechanisms in energy management, environmental protection, occupational safety, and human security can significantly reduce risks and enhance the resilience of the population to natural and man-made hazards. The implementation of these measures will contribute to the integrated development of the country and improve the quality of life of citizens.

Keywords

Energy saving; Environmental safety; Life; Sustainable development; Resource-saving technologies

Introduction

The problems of energy management, ecology, labour protection, and human life safety are becoming critical both for individual countries and for the whole world, as they directly affect the quality of life and health of people and the state of the planet and are necessary for study in the modern world. Considering global challenges such as climate change, environmental degradation, growing demands for energy efficiency, and ensuring safe working conditions, there is a particular need to introduce the latest measures and tools that will contribute to achieving sustainable development. Energy management is a key aspect in the context of sustainable development because it is the effective management of energy resources that can reduce greenhouse gas emissions and the burden on the environment. Changing approaches to energy consumption, switching to renewable energy sources and introducing energy-saving technologies are becoming integral components of the new energy policy. Thereby, the role of energy management at the level of individual enterprises and institutions is also important, as it helps optimise energy costs and improve the efficiency of production processes.

In particular, it is important to consider environmental safety as an integral part of an integrated approach to environmental management. The introduction of environmental standards, monitoring of the state of the environment, and the use of the latest eco-technologies allow preserving natural resources and provide a clean environment for future generations. In addition, the role of innovative solutions in the field of waste management, water and air purification and the restoration of ecosystems affected by anthropogenic activities is important (Bochko, Zarichna and Kuziak, 2024). Ensuring safe working conditions is not only a moral obligation of employers but also an important factor in economic stability and reducing social risks. The latest approaches to occupational safety include the introduction of automated safety monitoring systems, the use of a new generation of personal protective equipment and regular training of employees on safety issues. In this context, the importance of an integrated approach to risk management is also notable, which considers not only physical but also psychosocial factors that can affect the health of employees.

Human life safety covers a wide range of measures aimed at ensuring the protection of the population in emergencies and man-made and natural disasters. The realisation of recent innovations in the field of risk management, the development of effective warning and evacuation systems, and conducting safety training are necessary conditions for minimising the negative consequences of such events. An important component of life safety is also to raise public awareness of the rules of behaviour in emergencies and first aid.

Many contemporary researchers explored this subject, offering diverse perspectives. For example, Alhashmi *et al.* (2019) provided a detailed overview of current research on energy management systems in buildings, highlighting technological innovations and challenges facing researchers. The impact of challenging environmental conditions and unpredictability on adolescent social and academic behaviour in nine countries was analysed in the study by Chang *et al*. (2019). In particular, Durachman *et al.* (2019) reviewed the structure, application, and control of energy management in various business areas, which highlights the importance of energy efficiency in today's market. Other studies have highlighted the importance of environmental aspects in various

contexts, namely, Dvořáková *et al.* (2024) investigated the inclusion of road environmental criteria in environmental impact assessment, highlighting the importance of integrating environmental standards into transport planning. The paper by Hammarfelt and Åström (2021) is also notable, which examines the role of bibliometric indicators in resource allocation, an important aspect of evaluating scientific research and its impact on society. In the context of modern research on energy management and ecology, researchers have considered various aspects related to the implementation of the newest technologies, analysis of social behaviour, and environmental challenges. These studies have highlighted important issues related to effective resource management and the impact of external conditions on people's behaviour. Holubiev and Simishko (2021) researched the use of web scraping and text analysis to analyse news articles about ecology, which allows identifying trends and problems related to environmental issues in the country.

In their study, Inshyn *et al.* (2019) considered the obligations of employers to ensure labour protection in Ukraine, which is an important aspect in the context of the social protection of employees. Researchers, Ishankhodjayev *et al.* (2021), directed research to the development of an algorithm for optimising energy-saving management processes in intelligent power systems, which indicates the desire to improve the efficiency of energy resources. Emphasising the relevance of solving the problems of urban ecology and sustainable development in the context of global environmental challenges, Khidiraliev *et al.* (2023) and Kozina and Bogdanova (2023) highlighted various approaches to environmental policy and the integration of digital technologies in sustainable development. Although the aforementioned studies covered many important aspects, some issues that require further attention remain. For example, little attention is paid to the integration of renewable energy sources into existing energy management systems and the social consequences that arise from the introduction of new energy technologies. The researchers also did not assess the long-term effects of environmental changes on public health, especially in urbanisation.

The study aimed to identify innovative approaches to the management of energy resources, environmental protection, and the assurance of labour safety and human life in Ukraine, drawing on the experiences of foreign countries. The objectives were:

1. Analyse current trends and approaches in the fields of energy management, ecology, labour protection, and human life safety.
2. Identify innovative mechanisms and methods used to improve the efficiency of energy resource management and environmental protection.
3. Investigate the effectiveness of implementing the latest measures to ensure labour and life safety at enterprises and organisations in Ukraine, considering the experience of foreign countries.

Materials and Methods

The examination of the latest measures and tools in the fields of energy management, ecology, labour protection, and human life safety was conducted based on an integrated approach. This approach refers to the combined use of quantitative and qualitative data across energy management, environmental protection, labour safety, and life safety to

develop adaptive strategies tailored to specific local conditions and challenges. It included several stages, namely:

Data Analysis

Data analysis included examining the current situation and analysing statistical data to introduce the latest mechanisms and technologies. Ensuring the successful implementation of the mechanisms depends on the current state of energy management, ecology, labour protection, and human life safety, which includes the collection of both quantitative and qualitative data. This allowed for a better understanding of the real needs and challenges that the organisation or society in general may face. Performance indicators, environmental impact data, energy consumption levels, and socio-economic factors were analysed based on data from the Ministry of Environmental Protection and Natural Resources of Ukraine (2023), State Statistics Service of Ukraine (2022), National Agency of Ukraine for Civil Service (2023), and State Emergency Service (2019). Only based on an integrated approach was it possible to develop effective strategies for implementing new mechanisms that were maximally adapted to specific conditions and provided the desired results. This study's integrated approach involved the parallel collection and analysis of qualitative data, such as expert assessments, regulatory document reviews, and case studies from Ukraine, Germany, Sweden, and Japan, and quantitative indicators, such as energy consumption levels, emission statistics, occupational injury rates, and emergency response times. The convergence of these data types allowed for a thorough assessment of current practices and made it easier to formulate recommendations specific to a given context.

Ukraine and three foreign countries were selected for the comparative analysis: Germany, Sweden, and Japan. The choice of these countries was based on their substantial achievements in implementing advanced technologies in these areas and their diverse approach to solving energy management, ecology, and safety issues. Germany was chosen because of its leadership positions in energy management and renewable energy. Germany is actively implementing the Energiewende strategy, which aims to fully switch to renewable energy sources and reduce CO_2 emissions. This experience is particularly relevant to Ukraine’s efforts to diversify its energy sources. Sweden was chosen due to its successful experience in environmental management and sustainable development. The country is one of the leaders in the introduction of “green” technologies, in particular, in waste management and the use of renewable energy. This can provide a useful model for Ukraine, which is still developing its infrastructure in this area. Japan was included in the analysis due to its innovative approach to technology in the field of life safety and disaster management. Since the accident at the Fukushima-1 nuclear power plant, the country has made substantial progress in strengthening energy security and improving environmental protection measures. The country’s expertise in this area offers important lessons for Ukraine, which shares vulnerabilities to man-made and natural disasters. Furthermore, these countries' varying geographic and demographic conditions present contrasts that allow for a more comprehensive understanding of how different systems might be effectively implemented in Ukraine's developing infrastructure. Other countries like Denmark and Norway were not selected for analysis because, while they excel in specific areas (such as Denmark’s leadership in renewable energy and Norway’s strong labour safety systems), their contexts and challenges differ

significantly from those of Ukraine. These factors make it more difficult to draw direct comparisons with Ukraine, where the energy transition and labour safety systems are still developing.

Analytical Framework

For evaluation and comparison, the following main criteria were used: efficiency of energy management implementation (reduction of energy consumption and transition to renewable energy sources), environmental sustainability (reduction of emissions and effective waste management), the level of labour protection (prevention of injuries and improvement of working conditions), and life safety of the population (protection from technogenic disasters and ensuring environmental safety) (Figure 1). Comparison of these indicators allowed not only to assess the success of individual countries but also to provide recommendations for improving the situation in Ukraine through borrowing effective practices.

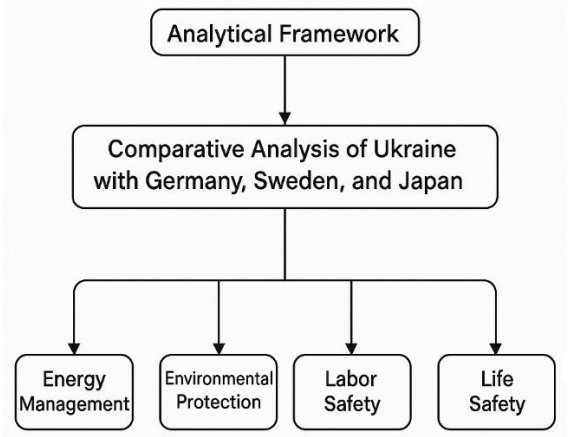

Figure 1: Analytical Framework of the Comparative Analysis

Figure 1 illustrates the comparison analysis's analytical framework, which integrates four important domains: energy management, environmental sustainability, labour protection, and human life safety. Through the identification of quantifiable indicators for each and their placement within a larger system of sustainable development goals, the framework conceptualises the interdependence of these domains. It illustrates a multi-criteria evaluation-based decision-making process in which results in one area (such as the proportion of renewable energy in energy management) can impact or be impacted by performance in another (such as the number of emissions impacting environmental sustainability). Contextual factors that limit the efficacy of policy implementation are also taken into consideration by the framework, including socioeconomic conditions, regulatory standards, and technical infrastructure.

The effectiveness of energy management implementation was measured by evaluating the decrease in overall energy consumption, the percentage of energy derived from renewable resources, and the contribution of energy-saving technologies to the reduction of greenhouse gas emissions to operationalise the evaluation and comparison criteria.

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Reductions in pollutant emissions, enhancements in air and water quality, and the efficiency of waste management systems, including recycling rates and waste-to-energy technologies, were all used to operationalise environmental sustainability. The frequency and severity of workplace injuries, the use of contemporary personal protective equipment, and the implementation of safety procedures and training initiatives targeted at enhancing general working conditions were all important indications of the degree of labour protection. Lastly, the development and implementation of disaster management systems, including emergency response plans, early warning technologies, and measures to protect the population from natural and man-made disasters, were used to evaluate the population's life safety, guaranteeing both short-term and long-term safety. These standards, which were measured using specific metrics, offered a thorough framework for evaluating how well each nation performed in these crucial areas.

The recommendations are based on a comparative analysis of data on the state of energy management, ecology, labour protection, and safety in Ukraine. In particular, the recommendations allowed for gradual improvement in practical efficiency, energy use, and environmental situation, and ensured better working conditions and human life safety in Ukraine. The comparative analysis used in this study provided a comprehensive approach to the investigation of the problem, considering both theoretical and practical aspects.

Specific Metrics

The efficiency of energy management implementation is measured by several key metrics. One of them is the decrease in energy use, expressed in kWh (kilowatt-hours) per GDP unit. This illustrates the degree of energy efficiency attained in economic production. The percentage of total energy consumption that comes from renewable energy sources is used to gauge the shift to renewable energy. Furthermore, the success of initiatives to lower carbon footprints is measured by the annual decrease in greenhouse gas emissions, which is expressed in tco2e (tonnes of CO_2 equivalent). Another important indicator used to evaluate the effectiveness of energy management strategies is energy intensity, which is the quantity of kWh used per unit of industrial output.

For the assessment of environmental sustainability, emissions reduction metrics included tonnes of CO_2, NO_x (nitrogen oxides), and SO_x (sulphur oxides) released per year. Metrics like the recycling rate (%), the tonnes of garbage kept out of landfills, and the tonnes of waste processed by waste-to-energy technologies are used to gauge how effective waste management is. Pollutant concentrations, such as $\mu g/m^3$ of PM2.5 (particulate matter) or NO_2 in the air, are used to measure improvements in air quality. Pollutant levels in water are expressed in mg/L, especially for organic, nitrate, and heavy metal contaminants. Finally, the percentage of electricity generated by renewable sources, such as wind turbines' contribution to the energy grid, is used to gauge the adoption of eco-technologies.

In labour protection, the injury rate per 100,000 workers per year was used to calculate occupational injuries. The percentage of workplaces that met national or international safety requirements was used to measure the application of safety regulations. The

proportion of workers in high-risk occupations who have access to sufficient personal protective equipment (PPE), such as gloves, helmets, and safety shoes, was used to gauge the availability of PPE. The percentage of workers who received safety protocol training and the number of hours of training each employee received annually were used to evaluate employee safety training.

The annual number of industrial accidents (chemical spills or nuclear events) was used to gauge life safety and protection from technogenic disasters. The average time it took for emergency services to respond to situations, measured in minutes/hours, was used to calculate emergency response time. The number of early warnings, reaction rate, and false alarm rate for technologies like flood, earthquake, or tsunami warning systems were used to measure how effective early warning systems were. The percentage of the population covered by emergency response plans was used to gauge the extent of disaster preparedness plans' coverage of the population. Lastly, the proportion of metropolitan areas with environmental safety laws or monitoring systems, including flood defences or sensors for air and water pollution, was used to assess environmental safety measures.

It is important to also acknowledge the limitations of the study. First, due to variations in reporting standards, data collection techniques, and temporal coverage, it was difficult to obtain and compare statistical data across the chosen nations of Japan, Sweden, Germany, and Ukraine. This might have had an impact on the comparative analysis's accuracy and consistency. Second, although the study included both qualitative and quantitative indicators, the latter were mostly derived from secondary sources like expert studies and regulatory reviews, which might not have the level of detail available from fieldwork or direct stakeholder interviews. Third, the ability to examine regional differences within nations was restricted by the emphasis on national-level statistics, especially in Ukraine, where post-war rehabilitation initiatives differ significantly by region.

Results

Current Trends and İnnovaties Technologies Applied in the Fields of Energy Management, Ecology, Labour Protection, and Human Life Safety

In the modern world, the issues of efficient use of energy, preserving the environment, ensuring workplace safety, and protecting human life have become particularly relevant. The latest measures and tools in these areas play a critical role in shaping the sustainable development of society and the economy. Energy management, which includes the introduction of renewable energy sources and infrastructure modernisation, environmental innovations aimed at reducing pollution and improving the quality of the environment, and modern approaches to labour protection and life safety, helps ensure safety, comfort, and stable development for future generations.

Energy management covers measures and technologies aimed at the efficient use of energy, reducing costs and environmental impact (Guliyeva, 2023). This includes the introduction of renewable energy sources such as wind turbines, solar panels, and geothermal systems and improving the energy efficiency of buildings and industrial processes. Energy management also includes developing strategies to reduce energy consumption, optimise its use, and reduce greenhouse gas emissions (Hruban *et al.*,

2023). Important aspects are the modernisation of infrastructure, the introduction of smart networks, and innovative energy storage systems. Ecology focuses on preserving the natural environment and implementing measures to reduce the negative impact of human activity. This includes waste management, improving water and air quality, and preserving biodiversity. Environmental initiatives may include recycling waste, reducing polluting emissions, and using eco-friendly technologies and renewable resources (Melnikova, 2021). Measures to adapt to climate change and protect natural ecosystems are also important.

CO_2 emissions in Central and Eastern Europe's manufacturing and energy sectors have been significantly impacted by post-2020 energy changes, especially those brought about by programs like the EU Green Deal. Reducing emissions, particularly in the energy sector, has been made possible by the drive for the use of renewable energy, rules governing foreign direct investment (FDI), and increased electricity costs. Consuming renewable energy has been shown to reduce emissions since it encourages cleaner energy behaviours, which is in line with EU climate goals (Simionescu and Radulescu, 2025). Furthermore, FDI might eventually result in higher emissions if environmental controls are inadequate, even though it initially helps create cleaner technology (the halo effect) (the pollution haven effect). Increased electricity costs for non-residential users also promote energy-saving behaviours, which helps the energy industry cut emissions.

Occupational health and safety are focused on ensuring the safety and health of employees in the workplace. This includes the development and implementation of safety standards, regular inspections of working conditions, training of employees, and the use of modern protective equipment. Occupational health and safety also include the implementation of safety management systems, risk assessment, and the development of procedures to prevent accidents and occupational diseases. Human life safety covers measures aimed at protecting the population from man-made and natural disasters. This includes the establishment of hazard early warning systems, the development of emergency response plans, and the provision of adequate civil protection. An important aspect is the infrastructure for rapid response and disaster recovery, as well as training the population and organisations in the field of safety and preparedness for possible emergencies.

Each of the industries is constantly developing and therefore needs to attract the latest technologies. They have a substantial impact on occupational health and safety, providing increased efficiency, accuracy, and safety in production processes and everyday life. Their implementation helps to reduce risks to people's health and life and improve working conditions. Modern automation and robotisation technologies substantially reduce the need for human participation in hazardous production processes. This allows avoiding exposure to harmful factors such as high temperatures, chemicals, and heavy physical activity and reduces the risk of injury. Robotic systems capable of performing complex and dangerous operations ensure continuous and stable operation without risking human life (Nussibaliyeva *et al.*, 2019).

Innovative materials and protective equipment also substantially increase occupational safety. New materials used for the manufacture of workwear provide reliable protection against physical, chemical, and biological hazards (Makhmudova *et al.*, 2019). For example, materials with high temperature resistance, resistance to chemicals, and

mechanical damage reduce the risk of injury in the event of an emergency. The digitalisation of risk assessment and management processes is an important aspect. Modern software solutions allow analysing risks, modelling scenarios for the development of emergencies, and planning measures for labour protection and life safety (Zarichuk, 2023). This allows predicting possible threats and developing strategies to minimise them, which reduces the overall level of occupational injuries and accidents.

The latest technologies presented in table 1 contribute to the creation of safer and more comfortable working conditions, reducing risks to the health and life of employees, and increasing the overall level of safety in production and life. They provide a comprehensive approach to addressing occupational health and safety issues, from monitoring and analysis to training and protection, which minimises risks and ensures safety at all stages of the production process.

Table 1: Types of modern technologies in the field of energy management

Technology	*Operating principle*
Wind power	Using kinetic wind energy to rotate the turbine blades that generate electricity
Solar energy	Conversion of solar radiation into electricity using photovoltaic panels
Geothermal energy	Using heat from the Earth's interior to generate electricity and heat
Biofuels	Use of organic materials (biomass) for energy production

Other types of energy technologies that can improve energy management are also actively developing. For example, hydrogen energy is promising because hydrogen can be used as a clean energy source, and its use in fuel cells allows the generation of electricity without CO_2 emissions. Another important area is energy technologies using ocean energy, such as wave and tidal energy, which can provide substantial amounts of renewable energy through continuous natural processes. New approaches to energy storage, such as improved batteries and energy storage technologies in pumped storage plants, are also important. The development of these technologies can substantially improve the efficiency of energy management, ensuring the stability and reliability of energy supply in the face of growing demand and changing climatic conditions. For example, today Internet of Things (IoT) and artificial intelligence technologies are often used in monitoring and control systems, which contributes to improving the level of security (Semenenko *et al.*, 2024). For example, IoT sensors can monitor the condition of equipment, detecting potential malfunctions before they cause accidents. Intelligent monitoring systems can automatically stop the production process if a hazard is detected, thereby preventing accidents and catastrophes (Babak *et al.*, 2021). Virtual and augmented reality tools open up new opportunities for the training and professional development of employees in the field of labour protection. They allow simulating dangerous situations and teaching correct actions in the event of accidents, which substantially increases the readiness of personnel to act in critical conditions without having to risk their health during training.

Factors Affecting the Fields of Energy Management, Ecology, Labour Protection, and Human Life Safety

In addition to the latest technologies, several other factors affect the development of energy management, ecology, labour protection, and human life safety. In particular, socio-economic factors play a key role in the introduction of new mechanisms, influencing the success and effectiveness of their integration into various fields of activity. These factors determine how well new technologies, policies, or methods will be adopted by society, how they will affect economic development, and what social consequences they may have. One of the main socio-economic factors is the level of economic development of a region or country. Highly developed economies usually have more resources to invest in the latest technologies, which ensures faster implementation of new mechanisms. In such circumstances, innovation can have a more effective impact on increasing labour productivity, improving living standards, and economic growth in general. But in countries with low levels of economic development, it may be difficult to finance new projects, which slows down the process of innovation.

Another important factor is the level of education and qualifications of the population. The introduction of new mechanisms often requires highly qualified specialists who can adapt to new conditions and master modern technologies. If the level of education in a country or region is insufficient, this may lead to the fact that new mechanisms will not be fully implemented or will not produce the expected results (Sosnytska *et al.*, 2019). Investment in education and training is essential to ensure successful innovation. Demographic indicators that influence the introduction of new mechanisms are also often considered. For example, an ageing population can lead to a shortage of labour, which encourages the active introduction of automation and robotisation in various industries. Moreover, excessively high demographic indicators in certain regions may necessitate the introduction of new mechanisms to ensure employment opportunities and maintain economic stability.

The above factors are effective only when there is a relationship between them. This provides an integrated approach to the implementation of environmental strategies, including the integration of various aspects of management and technologies aimed at achieving sustainable development and minimising the negative impact on the environment. This approach considers economic, social, technological, and environmental factors, which allows for to development and implementation of strategies adapted to specific conditions and needs. The foundation of an integrated approach lies in interdisciplinarity, which entails the collaboration of specialists from diverse fields such as environmental science, economics, engineering, sociology, and other relevant disciplines. This allows regarding all possible aspects of the environmental impact and developing balanced solutions. For example, when designing new production processes, it is important not only to assess their economic feasibility but also to pay attention to environmental risks and social consequences. One of the key elements of an integrated approach is the integration of environmental strategies into all stages of the product or service life cycle, from planning and development to waste management. This means that even at the design stage, it is necessary to consider possible environmental consequences and develop technologies that will minimise the impact on the environment. An important component is the implementation of the

principles of a circular economy, which provides for the reuse of resources and minimisation of waste.

An integrated approach also involves the active participation of all stakeholders, from governments and companies to local communities and community organisations. This is important to support and understand the need to implement environmental strategies at all levels. Public participation in the development and implementation of environmental strategies contributes to increased environmental awareness and preparedness for change. Evaluation and monitoring of results are an integral part of a combined approach. The implementation of environmental strategies requires constant monitoring of their effectiveness, analysis of the results obtained and adjustment of actions if necessary. This allows adapting strategies to changing conditions and ensures their effectiveness in the long term.

A comprehensive method for putting environmental strategies into practice ensures sustainable management of natural resources, reduces environmental risks and contributes to the achievement of sustainable development goals. It considers economic, social, and environmental aspects, which allows development balanced and effective strategies that meet the challenges of the modern world. Energy management, ecology, labour protection, and human life safety in the modern world are developing both in separate areas and about each other. Energy management focuses on reducing energy consumption and switching to renewable energy sources, which reduces the environmental impact and improves the quality of the environment. Environmental initiatives such as emission reduction and effective waste management have a direct impact on human health and safety. Occupational health and safety include the introduction of safe technologies and working conditions, which reduce risks to employees and improve the overall level of safety (Dautbayeva-Mukhtarova, Askarova and Suleymenova, 2023). Life safety is ensured through the development of early warning and disaster response systems, which help reduce the risks of man-made and natural hazards. All these aspects interact to form strategies for sustainable development and improving the quality of life.

Energy efficiency strategies aim to reduce energy consumption without reducing the volume of products or services provided (Zhangabay *et al.*, 2023). This is achieved by optimising the use of energy resources, introducing new technologies and changing management approaches. Effective adaptation of these strategies to specific conditions depends on several factors, such as geographical location, economic conditions, technological base, and social factors. One of the main energy efficiency strategies is the introduction of modern technologies and equipment that reduce energy consumption. This may include upgrading existing production processes, installing energy-efficient heating, ventilation, and air conditioning systems, and introducing renewable energy sources such as solar panels or wind turbines. For example, in regions with a large number of sunny days, installing solar panels can substantially reduce energy costs.

Adapting energy efficiency strategies to specific conditions requires considering local climatic and geographical features. For example, in cold regions, the main focus may be on building insulation and the efficiency of heating systems, while in warm regions, the optimisation of air conditioning and cooling systems. In addition, local resources can

play an important role in the choice of technologies: in regions with rich water resources, it is advisable to consider hydropower, and in regions – wind power. Economic conditions also influence the adaptation of energy efficiency strategies. In countries with limited financial resources, the introduction of expensive technologies can be problematic, so it is important to look for compromise solutions, such as gradual modernisation or the introduction of less expensive measures, such as replacing lighting with energy-efficient LED lamps (Ismayil-Zada, 2022). In more economically developed countries, where large investments are available, larger projects can be implemented, such as the construction of passive homes or the introduction of smart technologies for energy management.

Social and behavioural factors are important for adapting energy efficiency strategies. The introduction of energy-efficient measures often requires changing the behaviour of consumers and their attitude to energy use. This may include educational campaigns that raise public awareness about energy conservation, or incentives through financial instruments such as subsidies or tax breaks for implementing energy-efficient technologies. The regulatory framework and government support also affect the success of implementing energy efficiency strategies. Effective government policies that promote energy-efficient technologies, such as energy efficiency standards, building codes, or enterprise support programmes, make it much easier to adapt these strategies. Successful examples of such policies can be found in the European Union countries, where legally established energy efficiency goals encourage the development and implementation of appropriate measures. Energy efficiency strategies are adapted to specific conditions by considering local climatic, economic, social, and regulatory factors (Tagybayev *et al.*, 2023). This allows ensuring the most efficient use of resources and achieving substantial results in reducing energy consumption, which, in turn, contributes to sustainable development and environmental conservation.

The Effectiveness of Applying the Latest Approaches

Based on the above-mentioned theoretical information about the current state of energy management, ecology, labour protection, and human life safety, an important aspect is the comparison of efficiency in these industries of countries such as Ukraine, Germany, Sweden, and Japan, the indicators are presented in table 2 and figure 2.

Table 2: Comparative characteristics of the effectiveness of energy management implementation, environmental sustainability, the level of labour protection and life safety of the population in Sweden, Germany, Japan, and Ukraine

Country	*Efficiency of energy management implementation*	*Environmental sustainability*	*Level of labour protection*	*Life safety of the population*
Sweden	54% of energy comes from renewable sources; continuous reduction of	Low CO_2 emissions; efficient waste management with a high	High level of labour protection; low level of injuries due to the introduction of	High level of protection against man-made disasters; developed

Country	*Efficiency of energy management implementation*	*Environmental sustainability*	*Level of labour protection*	*Life safety of the population*
	energy consumption through innovative technologies and support programmes	level of recycling	modern safety standards	environmental safety systems
Germany	45% of energy comes from renewable sources; active support for the transition to renewable energy through subsidy programmes	Reducing CO_2 emissions; developed waste processing and management system	Strict occupational health and safety standards; low injury rate due to regular inspections and updating of standards	High level of preparedness for man-made disasters; powerful environmental monitoring systems
Japan	25% of energy comes from renewable sources; gradual reduction of energy consumption due to the introduction of energy efficiency technologies	Reducing CO_2 emissions through the introduction of modern technologies, a developed waste management system with an emphasis on recycling	High level of labour protection; constant introduction of innovations to improve employee safety	Strong systems of protection against natural disasters, considerable attention to the environmental safety of the population
Ukraine	The percentage of energy from renewable energy sources is about 10%; the introduction of energy efficiency is at an early stage.	High CO_2 emissions, low level of waste processing, need to improve the waste management system.	Low level of occupational health and safety; high level of injuries due to outdated safety standards	Low level of preparedness for man-made disasters; insufficiently developed environmental monitoring systems

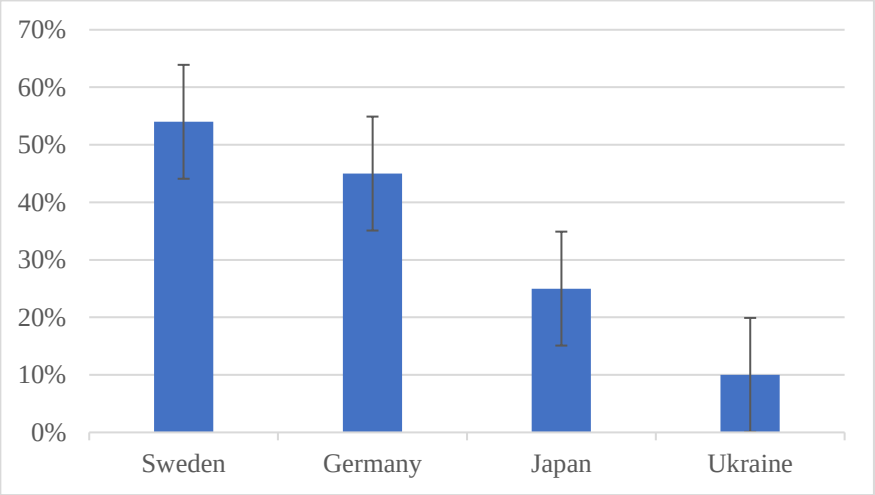

Figure 2: Efficiency of Energy Management Implementation by Country

The current situation in Germany, Sweden, Japan, and Ukraine demonstrates different levels of success in the areas of energy management, ecology, labour protection, and life safety of the population. Germany continues to lead the transition to renewable energy sources, where the share of renewable sources in the country's energy balance has reached more than 40% (Zbruc, 2024). Due to the Energiewende programme, Germany is actively upgrading its energy infrastructure, reducing CO_2 emissions and dependence on fossil fuels (Clean Energy Wire, 2024). Sweden, which already receives more than half of its energy from renewable sources, is implementing efficient energy-saving technologies that can substantially reduce its carbon footprint. The country has also succeeded in recycling, where 99% of garbage is recycled or burned to generate energy, making Sweden one of the world leaders in waste management (Kucherenko, 2024). Japan, which is focused on energy security after the Fukushima-1 disaster, is actively investing in innovative technologies to reduce dependence on imported energy carriers and improve environmental safety. While the country remains heavily dependent on fossil fuels, investment in renewable energy and intelligent energy management systems is key element of the development strategy.

Ukraine lags far behind Germany, Sweden, and Japan in all the areas under consideration. The main reasons for this lag include a low share of renewable energy sources, insufficient efficiency in reducing emissions and managing waste, and a weak occupational health and safety system. While Germany, Sweden, and Japan are actively implementing advanced technologies and effective strategies to address these issues, Ukraine is just beginning to take the first steps in these areas, which explains its lag.

In Ukraine, energy management is actively engaged in reducing energy consumption and improving energy efficiency (Ismayilzada *et al.*, 2024). The introduction of energy-saving measures has become particularly relevant due to the high dependence on imported energy resources and growing energy costs. According to the State Statistics Service of Ukraine (2022), in 2022, the energy costs of enterprises increased by 8% compared to the previous year. One striking example is the introduction of energy audits and energy efficiency programmes in industry and housing. In 2023, more than 1,000

projects for energy modernisation of buildings were implemented in Ukraine, which reduced energy consumption by 15-20% compared to previous indicators. This includes facade insulation, the installation of energy-efficient windows and heating systems.

Ukraine has also made some progress in the field of ecology, although the challenges remain substantial. According to the Ministry of Environmental Protection and Natural Resources of Ukraine (2023), the level of air pollution in cities has decreased by 10% over the past five years due to the introduction of new environmental regulations and restrictions on emissions of pollutants. One of the substantial projects is the development and implementation of a national waste management strategy. In 2022, Ukraine managed to reduce the volume of solid household waste sent to landfills by 12% due to the expansion of its recycling system. However, the fight against water pollution requires further efforts. Recently, Ukraine signed an agreement with the European Union on cooperation in the field of ecology, which provides for the modernisation of wastewater treatment and the improvement of water quality in rivers.

Labour protection is critical to ensuring employee safety. In Ukraine, there is a gradual improvement in this area due to changes in labour legislation and the introduction of new safety standards. According to the National Agency of Ukraine for Civil Service (2023), the number of accidents at work decreased by 5% in 2023 compared to the previous year. An example of improvement is the project “Safe working environment”, implemented in the metallurgical industry. As part of this project, equipment was upgraded, the level of training of employees was increased, and new security monitoring systems were introduced. This reduced the injury rate by 8% per year.

Life safety covers a wide range of issues, from protection from natural disasters to ensuring civil safety. Regular training and inspections of civil protection systems are conducted in Ukraine. According to the State Emergency Service (2019), the number of exercises conducted has increased by 20% over the past three years, which has improved emergency response readiness. In particular, in 2023, Ukraine implemented a project to modernise emergency early warning systems, including the installation of new warning systems and updating the infrastructure for rapid response. This has helped reduce emergency response times by 15%, which is a substantial improvement in life safety. The current state of Ukraine in the areas of energy management, ecology, labour protection, and life safety demonstrates positive changes, although challenges remain. Various projects and initiatives implemented in the country contribute to improving the situation in these areas and bring Ukraine closer to European standards.

According to the conducted study, recommendations were made to ensure the best conditions for the development of energy management, ecology, labour protection, and safety in Ukraine. To improve energy management, Ukraine should adopt Germany’s feed-in tariff model for solar energy and expand investment in wind energy infrastructure, particularly in coastal and steppe regions where wind potential is high. This will reduce dependence on fossil fuels and decrease CO_2 emissions, contributing positively to the environmental situation. Additionally, the development of smart grids and energy storage infrastructure will ensure the stability of the energy supply, especially as the share of renewable energy increases. In the field of ecology, waste management measures should be strengthened by introducing modern waste-to-energy technologies, inspired by

Sweden's recycling programs, and establishing municipal recycling initiatives. Developing and implementing effective programs to reduce air and water pollution is also critical, with a particular focus on improving wastewater treatment systems and reducing industrial emissions, especially in regions with high industrial output, as seen in Germany's environmental regulations. To enhance labour protection, it is necessary to align labour safety standards with EU regulations, similar to Japan's occupational health and safety measures, implement regular workplace inspections, and increase employee safety training programs using innovative technologies such as AI-based risk monitoring systems. In the field of life safety, Ukraine should modernise emergency response infrastructure by introducing automated early warning systems and developing regional disaster preparedness plans, similar to the strategies employed in Japan's post-Fukushima disaster response. The implementation of these measures will contribute to the integrated development of the country and improve the quality of life for citizens.

The implementation of these recommendations will help Ukraine gradually increase energy efficiency, improve the environmental situation, and ensure better working conditions and human life safety.

Discussion

The results of research in the fields of energy management, ecology, labour protection, and human life safety indicate the importance of introducing the latest measures and tools to ensure sustainable development and improve the quality of life. In particular, the integration of modern technologies and methods of energy management in various sectors of the economy is one of the key conditions for reducing energy consumption and improving resource efficiency. International experience in these areas plays a substantial role in implementing best practices that contribute to the modernisation of existing systems and improving life safety. The experience of the world's leading countries, in particular Sweden, Germany, and Japan, shows that an integrated approach to energy management and ecology can substantially improve the level of life safety of the population. In these countries, energy monitoring and management systems are widely used, which allow for quick responses to changes and minimise the risks associated with the use of energy resources.

Modern cities face challenges related to environmental safety (Buzhyn, 2023). For example, Abanina, Sukhova and Permykov (2023b) reviewed the implementation of effective management mechanisms and the integration of environmental standards that can substantially reduce the negative impact of urbanisation on the environment. These formulations are consistent with the results of other modern researchers, namely, Abanina, Agapov and Plotnikova (2023a), who actively worked to improve environmental safety through international cooperation and emphasised the importance of this process, stressed the need to integrate efforts to achieve higher environmental standards in the region. However, attention to specific regional challenges and strategies for integrating environmental safety in different economic and cultural contexts should be paid, which is confirmed by the information provided in the current study and is of great importance for adapting international practices to local conditions.

The results of the study showed that the safety of human life depends on effective risk management of modern threats. This judgment was confirmed in the papers of Akhmadieva *et al.* (2019) and Kim *et al.* (2019). They considered the noxological approach (or risk management approach) as a means of ensuring integrated safety, which is becoming increasingly relevant in modern conditions and modern approaches to risk management in the field of occupational health and safety using the latest technologies, such as artificial intelligence for monitoring and predicting hazards. Modern energy management technologies open up new opportunities for improving energy efficiency (Tleppayev, Tovma and Zeinolla, 2016). Therefore, in this study, recommendations were proposed for Ukraine based on the experience of foreign countries in developing an energy management system that optimises energy consumption based on the user's schedule, which helps to reduce costs and increase efficiency.

Assumptions about the use of medical construction in environmental management and audit play a key role in a study by Kruzhevnikova (2023), which confirms the conclusions of a study on the importance of environmental standards in the design of innovative medical institutions and helps to ensure the safety and efficiency of resource use. To achieve this, it is important to incorporate integrated approaches to solid waste management, as they are essential for ensuring both economic and environmental sustainability. In particular, Kundariya *et al.* (2021) emphasised the importance of modern technologies for improving the efficiency of this process, which contributes to the achievement of long-term results.

Other studies, including the one by Qiu, Wang and Wei (2023), highlighted the problem of energy security in extreme natural events as an important component of energy management. The present paper also focuses on the need to increase preparedness for such events to maintain the stability of energy systems. Therefore, energy security and energy management in conditions of extreme natural events are considered according to the indicators of the State Statistics Service of Ukraine (2022).

The results obtained showed that one of the most important areas of reforming modern approaches in the field of energy management, ecology, and labour protection is the introduction of innovative technologies and techniques. The analysis has confirmed that the latest solutions, such as optimising energy systems, improving environmental practices, and improving labour protection, are crucial for sustainable development and safety. This view is also confirmed in the study by Liao (2022), which analysed the impact of occupational health and safety laws on sustainable economic development, highlighting the importance of a legal framework for maintaining occupational safety. In addition, Malik (2019) reviewed the positive aspects of simulation training in medical courses, illustrating the importance of innovative methods to ensure safety and improve learning efficiency.

An important component of the successful implementation of the latest measures and means for energy management, ecology, labour protection, and human life safety is the initial data from a modern study by researchers such as Mariano-Hernández *et al.* (2021), Philips, Jesús and Carmen (2020), Pronina and Piatykop (2022), and Sarwary (2023) on energy systems management strategies. In particular, modelling and optimisation processes are key to effective resource management. They examined the impact of labour

protection legislation on employee income, which highlights the link between protecting workers' rights and economic performance. The use of neural networks to detect violations in occupational health and safety indicates the growing role of modern technologies in ensuring safety (Quraishi *et al.*, 2024). Energy resource management demonstrates the importance of new approaches to energy management to achieve sustainable development.

Despite the numerous advantages associated with the introduction of new technologies and techniques in the fields of energy management, ecology, and labour protection, there are also serious challenges. Firstly, it is a matter of financing innovative projects, which often require substantial capital investments. The introduction of new systems and technologies can require large financial costs, which are not always available for many organisations and enterprises (Novykova *et al.*, 2023). These results are consistent with those obtained by Guo, Tang and Jin (2021), confirming that the successful implementation of new technologies requires a comprehensive approach that includes not only technical innovation but also human resources development.

In addition, it is important to pay attention to personnel issues. A study by Sevastyanov *et al.* (2020) shows that for the successful implementation of new practices, it is necessary to integrate modern technologies and provide training for specialists who can effectively apply the latest methods and technologies. This includes both the professional development of existing specialists and the training of new personnel who have modern skills to work in a rapidly changing environment. An important aspect of the successful implementation of the latest measures in the field of energy management and ecology is the integration of environmental awareness and a sustainable approach to natural resource management (Lavrysh, Saienko and Kyrychok, 2021). The results of the study showed that the formation of ecological culture among the population and organisations is one of the vital factors of sustainable development. This is confirmed by the studies conducted by Sengupta (2022), Shackelford and McDougall (2023), Wang *et al.* (2021), and Zhang, Yang and Zhou (2020), which underlined the importance of environmental education and ecosystem regeneration to ensure long-term environmental stability.

The role of modern technologies in energy management and life safety is also important; the introduction of intelligent energy management systems substantially increases the efficiency of resource use and helps reduce costs. The study determined that such technologies can optimise energy processes and contribute to improving the overall safety of human life. In addition, the importance of considering labour protection and innovation in the field of sustainable development is emphasised. Ensuring appropriate working conditions and protecting workers is an integral part of life safety in the modern world, especially in the context of the introduction of new technologies and approaches in various industries.

Conclusion

In the course of the examination of the latest measures and means in the fields of energy management, ecology, labour protection, and life safety, it was possible to establish that the introduction of modern technologies is a critical factor in improving the efficiency

of resource use, reducing the negative impact on the environment and improving working conditions. It was confirmed that automated energy management systems, which are actively implemented in industry and everyday life, can substantially reduce energy costs and greenhouse gas emissions, which contributes to improving the environmental situation and reducing the impact on climate change. This highlights the importance of investing in new technologies and developments in the field of energy management and strengthening regulatory requirements for energy efficiency.

In the field of ecology, the study found that the use of “green” technologies and the development of waste management systems are effective strategies for reducing harmful emissions and pollution. The principles of the circular economy, which provide for the reuse of resources and minimization of waste, have proven effective in reducing the environmental burden on the planet. It is important to continue to implement and expand the use of such approaches in various sectors of the economy to achieve sustainable development. In the field of labour protection, it was stated that the introduction of the latest personal protective equipment and safe production technologies, together with systematic training of employees, substantially reduces the level of occupational injuries. Creating a safety culture in enterprises where employee safety becomes a priority is an important factor in preserving people's health and lives. In the field of life safety, an important result of the study is the confirmation of the effectiveness of emergency early warning technologies and emergency response systems. This includes not only technical means but also educational programmes for the population that help reduce risks in extreme situations.

However, the study has some limitations. The analysis focused mainly on general trends and theoretical aspects, without detailed consideration of specific practical cases and regional features. For instance, Ukraine's post-conflict infrastructure, especially in the eastern areas, has special energy management issues since continuing recovery efforts may cause electricity system rebuilding and renewable energy integration to go more slowly. This implies that the results obtained may require further refinement and adaptation to different contexts. Similarly, the analysis did not completely account for the socio-economic conditions in different parts of Ukraine, such as the patterns of energy use in rural vs urban areas or the distinction between industrial and agricultural areas. The qualitative indicators derived from the study point to the considerable potential of utilizing emerging technologies; however, further research and empirical validations are necessary for a more comprehensive understanding of their impact on various fields.

The results obtained indicate the need for further development of technologies and methodologies in these areas, in particular, by integrating innovative approaches and adapting them to the specific needs of industries. In the future, it is possible to improve the results by investigating more in-depth practical aspects, including a wide range of cases and analyzing regional characteristics. This will allow for a more accurate assessment of the effectiveness of implemented measures and developing recommendations for optimizing them in different contexts.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	Author 1	Author 2	Author 3	Author 4	Author 5
Conceived and designed the research or analysis	Yes	Yes	No	Yes	No
Collected the data	No	No	Yes	No	Yes
Contributed to data analysis & interpretation	Yes	Yes	Yes	No	No
Wrote the article/paper	Yes	Yes	Yes	No	No
Critical revision of the article/paper	No	No	No	Yes	Yes
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